JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, May 2010, Vol. 55, No. 3
doi: 10.1111/j.1556-4029.2010.01352.x
Available online at: interscience.wiley.com

TECHNICAL NOTE
GENERAL

Matthias Frank,[1,2] M.D.; Matthias Napp,[1] M.D.; Joern Lange,[1] M.D.; Rico Grossjohann,[1] Dipl.Phys.; Axel Ekkernkamp,[1,2] M.D., Ph.D.; and Achim G. Beule,[3] M.D.

Noise Trauma Induced by a Mousetrap—Sound Pressure Level Measurement of Vole Captive Bolt Devices

ABSTRACT: While ballistic parameters of vole captive bolt devices have been reported, there is no investigation on their hazardous potential to cause noise trauma. The aim of this experimental study was to measure the sound pressure levels of vole captive bolt devices. Two different shooting devices were examined with a modular precision sound level meter on an outdoor firing range. Measurements were taken in a semi-circular configuration with measuring points 0° in front of the muzzle, 90° at right angle of the muzzle, and 180° behind the shooting device. Distances between muzzle and microphone were 0.5, 1, 2, 10, and 20 m. Sound pressure levels exceeded 130 dB(C) at any measuring point within the 20-m area. Highest measurements (more than 172 dB[C]) were taken in the 0° direction at the 0.5-m distance for both shooting devices proving the hazardous potential of these gadgets to cause noise trauma.

KEYWORDS: forensic science, trauma mechanic, noise trauma, blank cartridge, vole captive bolt device, working equipment

Self-triggering weapons are used in many cultures as a pest control means to get rid of detrimental rodents. These primitive shooting devices are operated with ammunition containing projectiles or pellets and are completely legally unfounded (1).

In contrast to these illegally self-made shooting devices, vole captive bolt devices bear an official proof test mark and are commercially available. Age of consent is the only legal restriction. These vole captive bolt devices (vole guns) are stationary spring guns that are operated with cal. 9 × 17 mm industrial blank cartridges (cattle cartridges). A typical vole gun design is illustrated in Fig. 1. The shooting device is loaded through a screwable cartridge chamber and embedded into the vole's burrow. The vole triggers the firing mechanism by slightly touching a metal ring around the muzzle. The firing pin strikes the primer of the cartridge which ignites the powder. The vole is killed by the high-pressure gas jet that streams out of the muzzle (Fig. 2).

Since the beginning of the 20th century, these gadgets have been developed from hand-made muzzle-loading black powder shooting devices to industrially manufactured and worldwide distributed shooting traps (Fig. 3). Actually, there are two different models commercially available (Model Auber Aura, Hardt/Germany and Model Kieferle W2; Gottmadingen, Germany). Both models bear an approval test mark of the German National Proof House (PTB, Physikalisch-Technische Bundesanstalt) and therefore are officially sanctioned within all member states of the C.I.P. (Commission Internationale Permanente pour l'Epreuve des Armes à Feu Portatives, International Commission for the Proof of Small Arms) (2,3).

The growing popularity of these powder-actuated devices as a pest control mean has been accompanied by a rise in the incidence of both intentional and unintentional injuries because of these gadgets (Figs. 4 and 5). An accident analysis revealed improper use and recklessness while handling these devices as leading cause of unintentional injury (4). Outcome of these mutilating injuries is poor and characterized by extreme deterioration of hand function (5). It is previously unknown that these gadgets bear a certain hazardous potential to cause acoustic trauma. The impressive appearance of the ballistic injury patterns because of the high-pressure gas jet of these devices results in underestimation and even negligence of the concomitant noise trauma owing to the muzzle blast (Figs. 4 and 5).

Actually, there is no experimental investigation to assess the hazardous potential of these vole captive bolt devices to cause acoustic trauma. Increasing incidence of patients presenting with noise trauma (tinnitus, temporary/permanent hearing loss) because of these gadgets to our Emergency Department imposed an experimental investigation of the sound pressure levels (SPL) of these uncommon shooting devices.

Materials and Methods

A free field measuring site was developed for recording peak sound pressure levels (peak SPL) of two different commercially available vole captive bolt devices. The shooting devices (Auber Aura, Hardt/Germany and Kieferle W2; Gottmadingen/Germany) were attached to a tripod with a remote-control release. Distance between muzzle and ground was 1.6 m to avoid any measuring errors because of reflection.

[1]Department of Trauma and Orthopedic Surgery, Emergency Department, Ernst-Moritz-Arndt-University, Greifswald, Germany.
[2]Department of Trauma and Orthopedic Surgery, Unfallkrankenhaus, Berlin, Germany.
[3]Department of Otorhinolaryngology, Head and Neck Surgery, Ernst-Moritz-Arndt-University, Greifswald, Germany.

Received 26 Jan. 2009; and in revised form 27 April 2009; accepted 3 May 2009.

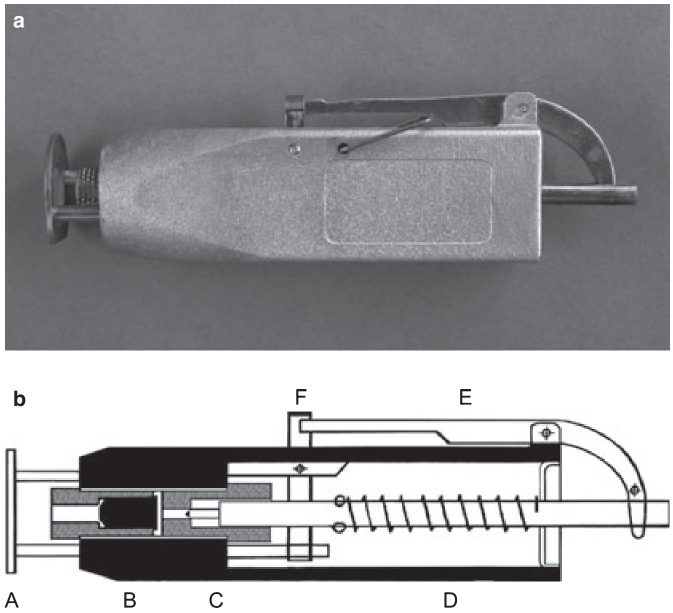

FIG. 1—*(a) Vole captive bolt device (Model Auber, approval number PTB 2). (b) Functional principle. The shooting trap is loaded with an industrial blank cartridge through the screwable explosion chamber B. Trigger mechanism A, firing pin C, firing pin spring D, cocking lever E, trigger device F.*

For measurement of the peak SPL, a modular precision sound level meter (Type 2250, High-level Pressure-field 0.25-inch microphone, Type 4941, 0.25-inch – 0.5-inch adaptor; Bruel & Kjaer, Naerum, Denmark) was used. Measurements were taken in C-weighting (dB(C), decibel). The microphone and measuring apparatus were also attached to a tripod.

To examine a possible directional characteristic, measurements were taken in a semi-circular configuration with measuring points 0° in front of the muzzle, 90° at right angle of the muzzle, and 180° behind the shooting device. Distances between muzzle and microphone were 0.5 m, 1 m, 2 m, 10 m, and 20 m. Ten measurements were taken at each site and averaged. Free field measurements were taken at an outdoor firing range.

Calibration was performed using an acoustic calibrator (Type 4231, Bruel & Kjaer, Naerum, Denmark) before and after each test sequence.

Commercial industrial blank cartridges (RWS Dynamit Nobel, Fuerth, Germany, caliber 9 × 17 mm, yellow mark, maximum energy value 700 J) which contain 390 mg of nitrocellulose charge and are legally assigned for the use in vole captive bolt devices were used for test shots. All cartridges were taken from the same ammunition lot. Statistical analysis was performed using SPSS 16.0.1 (SPSS Inc., Chicago, IL).

Results

Peak SPL showed a directivity with highest levels in the 0° direction (in front of the muzzle) and lowest levels behind the shooting devices (the direction facing away from the muzzle). SPL exceeded 130 dB(C) at any measuring point within the 20-m circular area.

Measurements showed higher peak SPL values for the model Kieferle W2 than for the model Auber Aura at any measuring point. Highest measurements were taken in the 0° direction (in front of the muzzle) at the 0.5-m distance (Kieferle mean SPL 172.5 dB(C), SD 0.9 dB(C); Auber mean SPL 172.1 dB(C), SD 1.4 dB[C]).

For the device manufactured by Kieferle, SPL were reduced on average 2.9 and 9.5 dB(C) when 0° direction is compared with the 90° and the 180° direction. For the device manufactured by Auber, SPL were reduced on average 2.6 and 3.2 dB(C) when 0° direction is compared with the 90° and the 180° direction. For detailed data and geometric distribution (near field) of the SPL measurements see Table 1 and Fig. 6.

Discussion

Although the functional principle of vole captive bolt devices is similar to blank cartridge handguns, the ballistic relevant

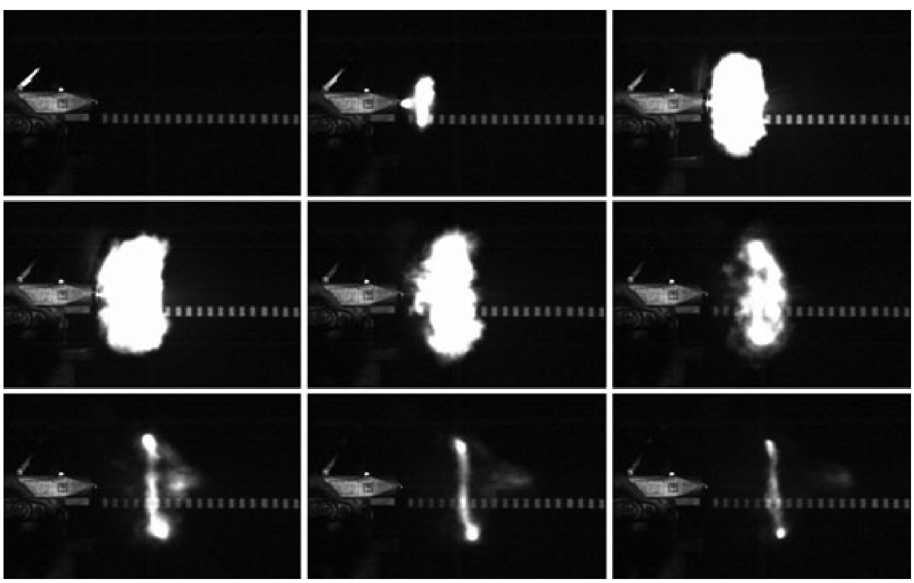

FIG. 2—*High-speed motion analysis of the muzzle flash of a vole captive bolt device (High-speed camera MotionXtra HG-100K, Redlake Digital Imaging Systems, Tallahassee, USA; frame rate 5000 frames/s). The initial muzzle flash consists of a fire-jet that streams out of the muzzle. The second flash is due to combustion of unburned gases (H_2 and CO) that leave the muzzle and react with the oxygen of the air surrounding the muzzle.*

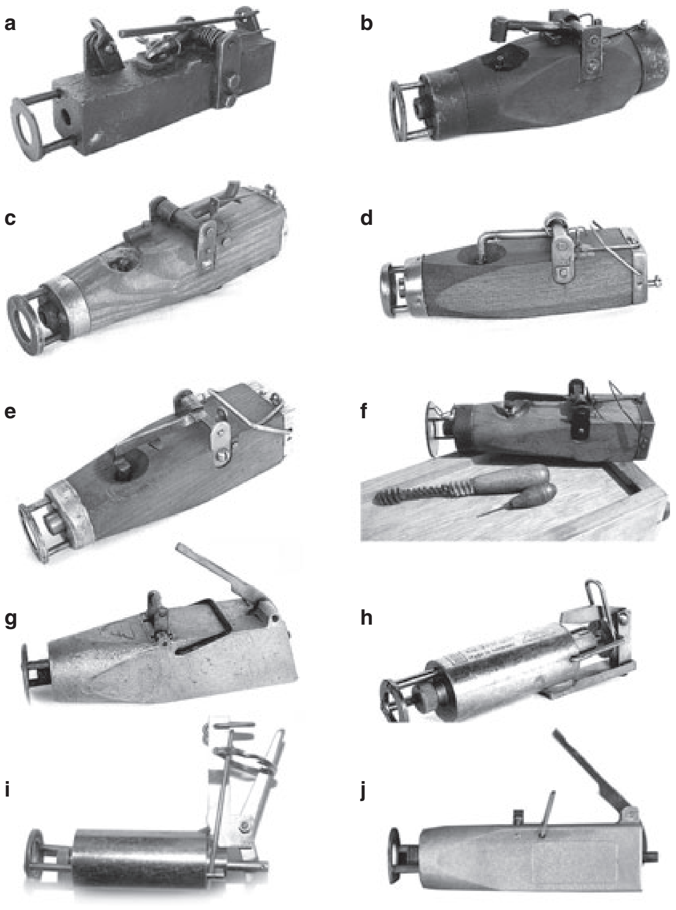

FIG. 3—*Technical development of powder actuated vole captive bolt devices. Muzzle-loading blackpowder shooting traps were developed in the Lake Constance area from the 1930s (a–f). In the 1950s they were technically refined and featured a screwable cartridge chamber. Since then, they have been mass-produced (g, h). Today, two different models are approved and commercially available (i Model Kieferle W2, j Model Auber Aura).*

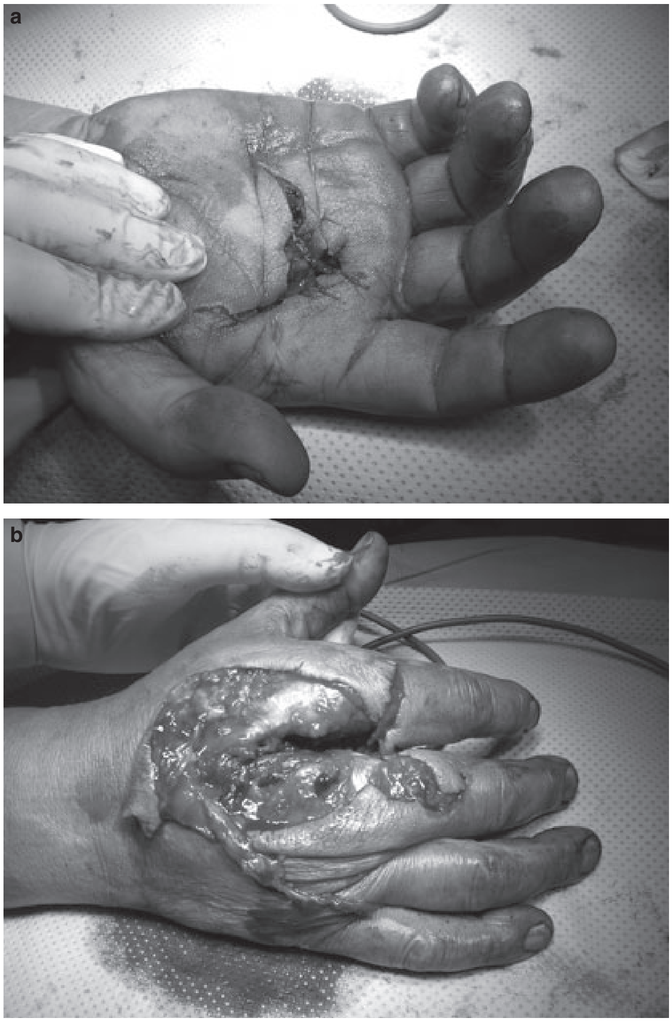

FIG. 4—*(a) Ballistic trauma to the right hand due to unintentional premature discharge of a vole captive bolt device. Entry wound of the focused gas jet at the palm. (b) Exit wound with disruption of the wound edge in a stellate fashion at the back of the hand. The right dominant hand is most susceptible to these injuries, most injured sites are the index, palm, and long finger (5). Surrounding powder tattooing at the palm indicates close contact shot.*

components are completely different (Fig. 1). Vole captive bolt devices are provided with a small tube of only 11 mm between cartridge mouth and muzzle, therefore they bear no barrel in the proper sense. In contrast to blank firing handguns, the muzzle of a vole captive bolt device has a much smaller diameter of only 4 mm. In conventional blank firing handguns, most of the firing gases burn out while streaming through the barrel. Ballistic of these extremely short barreled vole captive bolt devices is characterized by vast amounts of unburned firing gases and powder that are streaming out of the muzzle. The muzzle blast of a vole captive bolt device consists of two different reports that are superimposed and are perceived as one. The first report is caused by rapid expansion of the gas under high pressure. The second report is attributed to the combustion of unburned gases (H_2 and CO) that react with the oxygen of the air surrounding the muzzle (6).

Although the dimension of the caliber 9×17 mm industrial cartridges is identically equal to the caliber .380 cartridges which are used in blank firing revolvers, the charge of the industrial cartridges is much higher compared with the charge of the .380 cartridges (390 mg vs. 150 mg) (7).

As a result of these differences, neither ballistic data nor data regarding sound emission can be transferred from common blank firing handguns to vole captive bolt devices.

An experimental investigation of the ballistic background of these unique shooting devices revealed a firing pressure exceeding 100,000 kPa (1000 bar) in the explosion chamber of a vole captive bolt device. The muzzle velocity of the gas jet surpasses 2000 m/s. With regard to the ballistic effectiveness of these shooting traps, the energy density of the gas jet is up to 0.770 J/mm^2 for the close contact shoot which far surpasses the energy density required for causing penetrating wounds (0.1 J/mm^2) (8,9). These ballistic parameters far surpass the well-known parameters of blank firing guns. The small diameter of the muzzle of only 4 mm results in a very high-pressure gradient between muzzle and surrounding air.

SPL exceeded 130 dB(C) at any measuring point within the 20-m circular test area for both types of vole captive bolt devices. Marginal differences in the sound emission between the Kieferle and Auber devices might be attributed to different case designs. Peak SPL up to 174 dB(C) were measured at 0.5 m in front of the muzzle. This might be the distance to the operator's ear when a handheld shooting device is discharged unintentionally.

Impulse noise exposure to the human ear may result in various symptoms, ranging from permanent hearing loss, tinnitus, to changes in auditory sensitivity (temporary or permanent threshold shift [TTS, PTS]). Harmfulness of impulse noise is determined by

FIG. 5—*Ballistic trauma to the mouth (suicide attempt) using a vole captive bolt device and a 700 J industrial blank cartridge. Radial soft-tissue disruption of the upper lip due to rapid expansion of the blast wave. Starlike disruption of the tongue. Facial powder tattooing.*

TABLE 1—*Peak sound pressure levels (SPL peak, dB[C]). Mean of 10 shots at each measuring point, standard deviation in brackets.*

	20 m	10 m	2 m	1 m	0.5 m
Auber					
0°	139.4	145.3	159.9	165.6	172.1
	(0.9)	(0.3)	(1.1)	(1.0)	(1.4)
90°	135.0	141.0	155.1	161.2	168.0
	(1.1)	(0.7)	(0.6)	(0.8)	(1.1)
180°	134.7	141.3	154.0	161.0	166.3
	(0.9)	(1.2)	(1.1)	(0.8)	(1.1)
Kieferle					
0°	140.9	147.9	161.2	166.3	172.5
	(0.8)	(0.7)	(0.8)	(0.8)	(0.9)
90°	138.1	143.7	158.5	163.1	170.7
	(0.7)	(1.2)	(1.7)	(0.8)	(1.4)
180°	131.9	136.8	151.2	157.9	163.6
	(1.0)	(1.2)	(1.2)	(0.5)	(1.3)

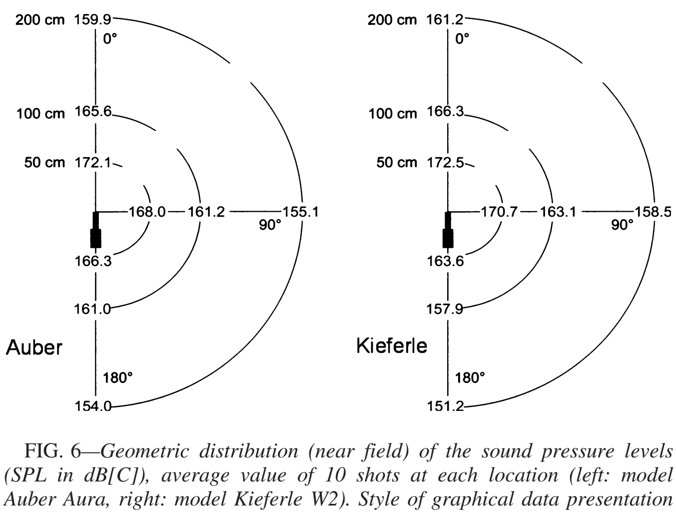

FIG. 6—*Geometric distribution (near field) of the sound pressure levels (SPL in dB[C]), average value of 10 shots at each location (left: model Auber Aura, right: model Kieferle W2). Style of graphical data presentation with reference to (12).*

the peak SPL (10). Damage threshold peak levels are reported in literature between 130 and 140 dB(C) (10,11). Noise exposure beyond these limits may increase the probability of temporary or permanent hearing loss. One should be aware that a 10 dB increase in SPL is equivalent to a threefold increase in pressure on the eardrum.

Rothschild et al. investigated peak SPL of starter's pistols that are also operated with blank cartridges. He also observed a directional characteristic concerning the emission of noise. At a distance of 1 m (0° shooting direction), nearly all weapons exceeded 160 dB(C), maximum peak SPL reached more than 180 dB(C) (12). Using a similar test setup, Just et al. (13) found peak SPL up to 157 dB(C) and also a directivity of the sound emission.

The high emission of noise measured in this experimental setup confirms the high probability of acute noise-induced hearing loss after unintentional premature discharge of vole captive bolt devices. While in the acute situation the patient may deny the subjective impression of hearing loss, objective evaluation should be performed. Both the damage of the direct ballistic site (normally occurring at the hand) and the emergency situation, including the psychological distress and possible suicidal background of the incident, will draw patient's and forensic expert's attention away from this concomitant injury. A traumatic perforation of the ear drum may occur if the tympanic membrane is altered by previous illness or operation and should therefore be excluded via otomicroscopy. For personnel using these shooting traps regularly, the use of hearing protectors, especially ear muffs, is strongly recommended.

Direct ballistic trauma to the ENT (Ear, Nose and Throat) area as seen in Fig. 5 must be considered as lifethreatening because of the high density of underlying soft vital organs in the cervical and maxillofacial region. Fatalities are usually the result of massive blood loss because of the rupture of large blood vessels resulting in rapid exsanguination or blood aspiration (14,15). Air embolism might also be a consequence of this unique injury mechanism.

Vole captive bolt devices are stationary shooting devices and are not intended for handheld use. In contrast to other powder-actuated tools such as nailguns, there are no noise criteria or thresholds provided by the statutory accident insurance to define and limit noise emission of these gadgets. Neither the instruction manual nor the devices bear any warnings of the hazardous noise emission. In spite of sufficient mechanical security mechanisms, unintentional premature discharge can and does occur. Wearing hearing protectors such as ear muffs while handling these devices might help to limit the consequences of accidental discharge of these shooting traps. Moreover, the device should be marked with a warning label concerning the potential hazard of noise-induced hearing loss.

To conclude, this investigation enhances the forensic examination of incidents because of vole captive bolt devices by their hazardous potential to cause severe noise trauma. There is no doubt that the ballistic injury patterns draw the attention because of their impressive appearance, although both the forensic expert and the clinician are strongly recommended not to neglect the concomitant noise trauma because of this uncommon vole trap.

Acknowledgments

The authors thank the Landesamt fuer Umwelt, Naturschutz and Geologie (LUNG) in Guestrow, Mecklenburg-Western Pomerania, and Dipl.-Ing. Stefan Frank for technical help. The authors also extend deep appreciation to G. Jost for permission to use the photographs of the historic traps and for providing some information on the historic background.

References

1. Yilmaz R, Birincioglu I, Cakir I, Uner HB, Acikgöz D, Scekin C. Mole guns in Turkey in 2003–2005. J Forensic Sci 2007;52:114–5.
2. Physikalisch-Technische Bundesanstalt (PTB), Zulassungsliste §§ 7&8 BeschG, 2009, http://www.ptb.de/de/org/1/13/133/download/Zulassungsliste.pdf (accessed April 23, 2009).
3. Commission Internationale Permanente pour l'épreuve des armes à feu portatives (C.I.P.), 1994, http://www.cip-bp.org/ (accessed April 23, 2009).
4. Frank M, Schmucker U, Zach A, Hinz P, Stengel D, Ekernkamp A, et al. Harm set, harm get. Hand injuries caused by vole captive bolt devices. Forensic Sci Int 2008;176:258–62.
5. Frank M, Schmucker U, Napp M, Stengel D, Hinz P, Ekkernkamp A, et al. Humane killers, human injury. Functional outcome of vole captive bolt injuries. J Trauma 2009;67(3):617–23.
6. Kneubuehl BP, Coupland RM, Rothschild MA, Thali MJ. Wundballistik—Grundlagen und Anwendungen. Berlin, Heidelberg, New York: Springer-Verlag, 2008.
7. Rothschild MA, Tschan F. Construction and components of blank cartridges. Rechtsmedizin 1998;8:94–7.
8. Frank M, Philipp KP, Franke E, Frank N, Bockholdt B, Grossjohann R, et al. Dynamic pressure measurement of vole captive bolt devices. Forensic Sci Int 2009;183:54–9.
9. Bir CA, Stewart SJ, Wilhelm M. Skin penetration assessment of less lethal kinetic energy munitions. J Forensic Sci 2005;50:1426–9.
10. Gupta D, Vishwakarma SK. Toy weapons and firecrackers: a source of hearing loss. Laryngoscope 1989;99:330–4.
11. US Department of Defense, MIL-STD-1474 D Design criteria standard noise limits. 1997, http://www.silencertests.com/docs/mil-std-1474d.pdf (accessed April 23, 2009).
12. Rothschild MA, Dieker L, Prante H, Maschke C. Peak sound pressure levels of gunshots from starter's pistols. HNO 1998;46:986–92.
13. Just T, Kramp B, Pau HW, Sievert U, Wild W, Kunde B, et al. Measurement of sound pressure levels and determination of pulse durations of commercially available blank guns. Otorhinolaryngol Nova 1998;8:297–303.
14. Rothschild MA, Vendura K. Fatal neck injuries caused by blank cartridges. Forensic Sci Int 1999;101:151–9.
15. Bungardt N, Dettmeyer R, Madea B. Suicidal shot in the mouth with an unmodified blank cartridge pistol. Arch Kriminol 2005;216:1–6.

Additional information and reprint requests:
Matthias Frank, M.D.
Ernst-Moritz-Arndt-University Greifswald
Trauma and Orthopedic Surgery, Emergency Department
Sauerbruchstrasse
17475 Greifswald
Germany
E-mail: matthias.frank@uni-greifswald.de